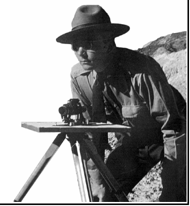
NATURAL RESOURCE MONITORING PARAMETERS

Shoreline Position



Brief Description: The position of the shoreline along ocean coasts and around inland waters (lakes) varies over a broad spectrum of time scales in response to shoreline erosion (retreat) or accretion (advance), changes in water level, and land uplift or subsidence [see relative sea level; surface displacement]. Long-term trends in shoreline position may be masked in the short term by variations over periods of 0.1-10 years or more, related, for example, to individual storms, changes in storminess, and El Niño/Southern Oscillation effects. Shoreline position reflects the coastal sediment budget, and changes may indicate natural or human-induced effects alongshore or in nearby river catchments. The detailed shape and sedimentary character of a beach (e.g. beach slope, cusp dimensions, bar position and morphology, barrier crest and berm elevation, sediment size and shape) are highly sensitive to oceanographic forcing, including deep-water wave energy, nearshore wave transformation, wave setup, storm surge, tides, and nearshore circulation: morphodynamic adjustments and feedbacks are common. Qualitative assessments of shoreline morphology can be used as a proxy for shore-zone processes, partially substituting for more quantitative measures of shoreline change where these are not available.

Significance: Changes in the position of the shoreline affect transportation routes, coastal installations, communities, and ecosystems. The effects of shoreline erosion on coastal communities and structures can be drastic and costly. It is of paramount importance for coastal settlements to know if local shorelines are advancing, retreating or stable. Rates of recession as high as 5-10 m/yr have been measured in many places around the world, and much higher rates have been recorded locally. Coastal erosion in the USA alone is estimated to cost $700 million annually. Floods related to recent storm surges along the low-lying coasts of the Bay of Bengal have caused as many as 50,000 deaths per event.

Environment where Applicable: Ocean coasts, lake shores, estuaries.

Types of Monitoring Sites: Cliffs, beaches, coastal dunes and wetlands [see dune formation and reactivation; wetlands extent, structure and hydrology] and other shoreline settings.

Method Of Measurement:
Quantitative: Using conventional ground survey and other methods (simple rod and tape profiles, levelling, electronic total-station surveys, airphotos, GPS, analysis of old maps and charts), the following parameters are commonly monitored:
1. Width of the dry beach, position of the mean water line, the high water line, or the base of the beach where well defined. However, measurements are subject to local variations in water level and sand storage, and it may take 10 years or more to separate long-term trends from daily, annual or multi-annual variations.
2. Changes in position of top and toe of bluffs. These can provide proxies of shoreline movement, though in the short term they can move in opposite directions to those of the shoreline.
3. Changes in position of foreshore and backshore vegetation: note that the vegetation line can move in the short term in an opposite direction to that of the shoreline.
4. Beach profiles along sequential transects normal to the shoreline. Best for evaluating seasonal or other short-term shoreline movements, and beach morphology.
To help in understanding why shoreline change is occurring, it can be helpful to measure:
5. Water levels, wind speed and direction, storm waves, and coastal currents; these can be related to shoreline change. Storm surge limits and other high-water indicators of meteorological or oceanographic forcing are especially important.
6. Losses or gains of sediment (sediment budget) in specific coastal compartments or cells. A sediment surplus is typically associated with an advancing shoreline, whereas a deficit may lead to shoreline retreat. The procedure attempts to identify where sediment is coming from and where it is being deposited (i.e. sources and sinks). Common sources are coastal rivers, updrift beaches or bluffs, and the inner continental

shelf. Common sinks are coastal dunes, storm washovers, tidal deltas, accreting beaches, and the inner continental shelf.

Qualitative: Simple and immediate visual assessments of shore morphology can indicate the state of the shoreline (eroding/accreting). These should be supplemented by photographs and videos taken from low-flying aircraft, of the mean or high water line, the limit of vegetation, the landward limit of washover sedimentation, or the base or top of a coastal cliff. Simple monitoring can be done by repeated assessments of change along a particular stretch of shoreline, such as an increase in the degree of erosion at individual sites or an increase in the number of eroding sites in a particular region.

1. The following features indicate contemporary or recent erosion: scarped or breached dunes; bluffs without talus ramps or toe deposits; peat, mud or tree stumps in the surf zone; toppled trees along the shore; narrow beaches; and washover fans. Coasts undergoing severe erosion are commonly marked by: absence of dunes and vegetation, presence of a washover apron, tidal channels that extend into the surf zone, unvegetated bluffs without ramps at their base (active wave-cutting), and man-made shoreline structures now located offshore. Actively eroding rocky shorelines are characterized by rock falls, collapsing caves and seastacks.

2. The following features indicate accreting or stable coasts: robust dunes, newly formed beach ridges, wide beaches with well-developed berms, absence of overwash or dune breaching, well-developed beach vegetation (berm colonizers, dune grasses and shrubs, healthy forests extending to shoreline), well-vegetated bluff face and toe, substantial toes at base of bluffs or cliffs.

3. Long-term shoreline retreat may be marked by the presence on the foreshore of material distinct in texture or composition, such as older relict sediments, backshore peat or shell assemblages underlying foreshore deposits.

Frequency of Measurement: Seasonal, before and after storms. Semi-annual or annual, once seasonal variability is established.

Limitations of Data and Monitoring: Results are site specific, temporally and spatially discontinuous, and of varying quality. Historical records are commonly short. Qualitative results can be misleading, and many methods have severe limitations. Sediment budget calculations are hampered by lack of accurate data on coastal bathymetry and topography; map analysis by lack of accurate maps and reliable datum levels; photo analysis by radial distortion and tilt and by difficulties in determining high-water lines.
Adjacent shoreline segments may respond differently to the same environmental conditions. Gravel-dominated coastal systems may exhibit progressive beach crest growth and sediment sorting that can lead to increased stability with time or to a growing potential for rapid destabilization during extreme events. Changes in relative sea level and in sediment supply are critical factors in coastal evolution and in the response of shorelines to environmental change. In some cases sediment supply may be controlled by processes external to the coastal system, such as glacier-burst floods, changes in ice-marginal drainage, or artificial river impoundment.

Possible Thresholds: Subtle changes in sediment supply or other factors can shift the balance between shoreline stability or accretion and shoreline erosion, with significant implications for coastal ecosystems and settlements.

Key References:

Berger, A.R. & W.J.Iams (eds). Geoindicators: Assessing rapid environmental changes in earth systems. Rotterdam: A.A. Balkema. (see papers by Forbes & Liverman, Morton, and Young et al.).

Carter, R.W.G. 1988. Coastal environments: an introduction to the physical, ecological and cultural systems of coastlines. London: Academic Press.

Carter, R.W.G. & C.D.Woodroffe (eds) 1994. Coastal evolution: Late Quaternary shoreline morphodynamics. Cambridge: Cambridge University Press. (especially paper by Cowell and Thom on coastal morphodynamics).

Godschalk, D.R., D.J.Brower & T.Beatley 1989. Catastrophic coastal storms and hazard mitigation and development management. Raleigh NC: Duke University Press.

Pilkey, O.H., R.A.Morton, J.T.Kelley & S.Penland 1989. Coastal land loss. Washington, American Geophysical Union.

Related Environmental and Geological Issues: Changes in the shoreline affect the distribution and functioning of salt marsh, estuarine and littoral ecosystems, as well as the planning and management of coastal resources and built structures.

Overall Assessment: The shoreline position is perhaps the most important geoindicator for low-lying coastal communities and islands. Quantitative methods are best for predicting future shoreline movements. Qualitative indicators of shoreline position and morphology are practical, inexpensive, and rapid guides to coastal erosion.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.